Transmitter Beam Bias Verification for Optical Satellite Data Downlinks with Open-Loop Pointing – the 3-OGS-Experiment

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- **The OSIRISv1 on Flying Laptop Satellite**
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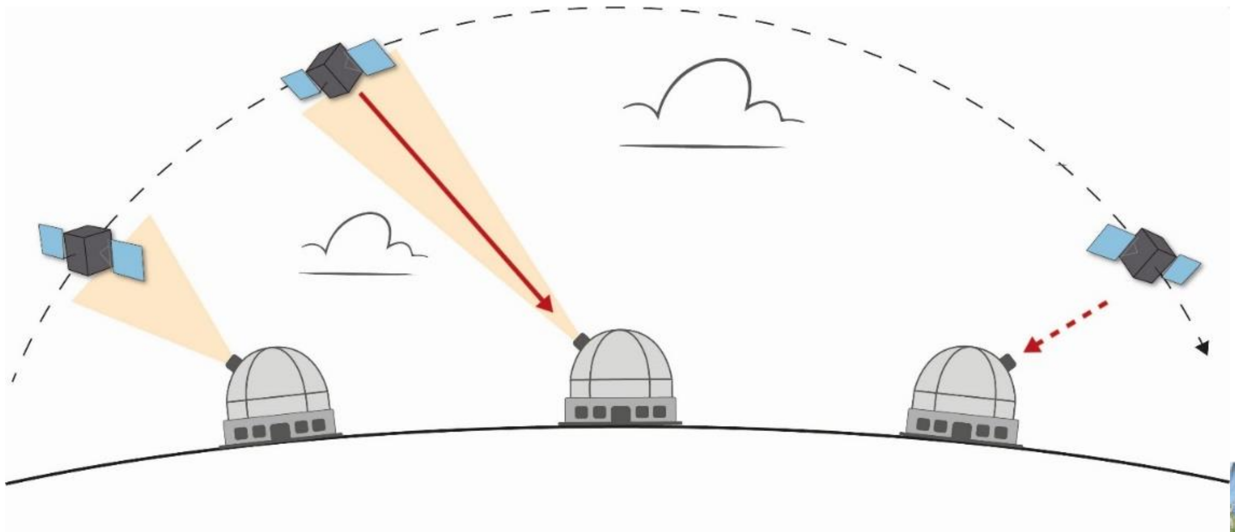
- **Summary**

Why go for “LASER” in Data Downlinks from LEO Satellites?

- The RF frequency bands are already crowded from terrestrial mobile telecom and space links, much more traffic is expected in the next years
- Directed Optical Links allow smaller transmitter structures (lenses) and also ground receivers (telescopes)
- More power efficient and higher data rates possible: few Watt allow several GigaBit/s downlink speed
- Further optical technologies can be applied like Quantum Communications (QKD) or precise timing by optical intersatellite links, as well as coherent communication and sensor technologies

- Simple OLEODL: focus on Optical On/Off-Keying (O3K) transmission of up to 10Gbps onto bulk Avalanche Photo Detectors in the OGS



OLEODL: *Optical Low Earth Orbit data DownLink*
OGS*: Optical Ground Station*

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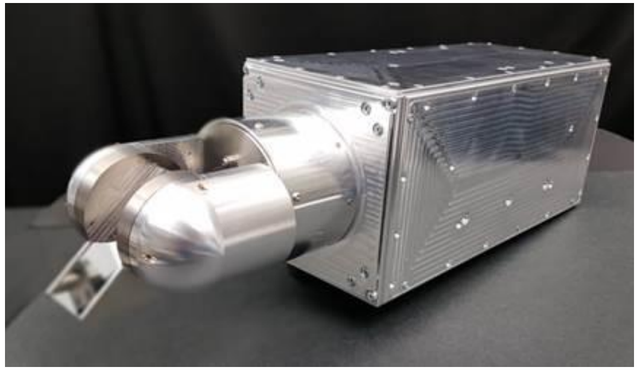
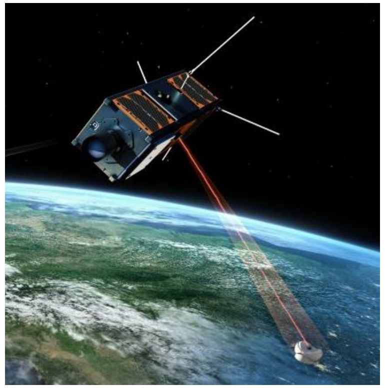
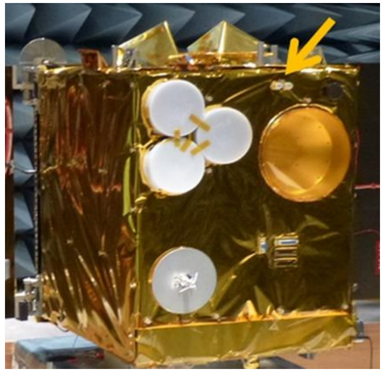
Types of Laser Transmitters for OLEODL



a)
Terminal with Coarse-Pointing Assembly for hemispherical Field-of-View, and active tracking of a Beacon from Ground
→ *OSIRISv3 on Titania*



b)
Dynamic Coarse Body-Pointing by Satellite during OGS-overflight; only the Fine-Pointing by Tracking of the Beacon is done through the Optical Terminal
→ *OSIRIS4CUBE on PIXL*

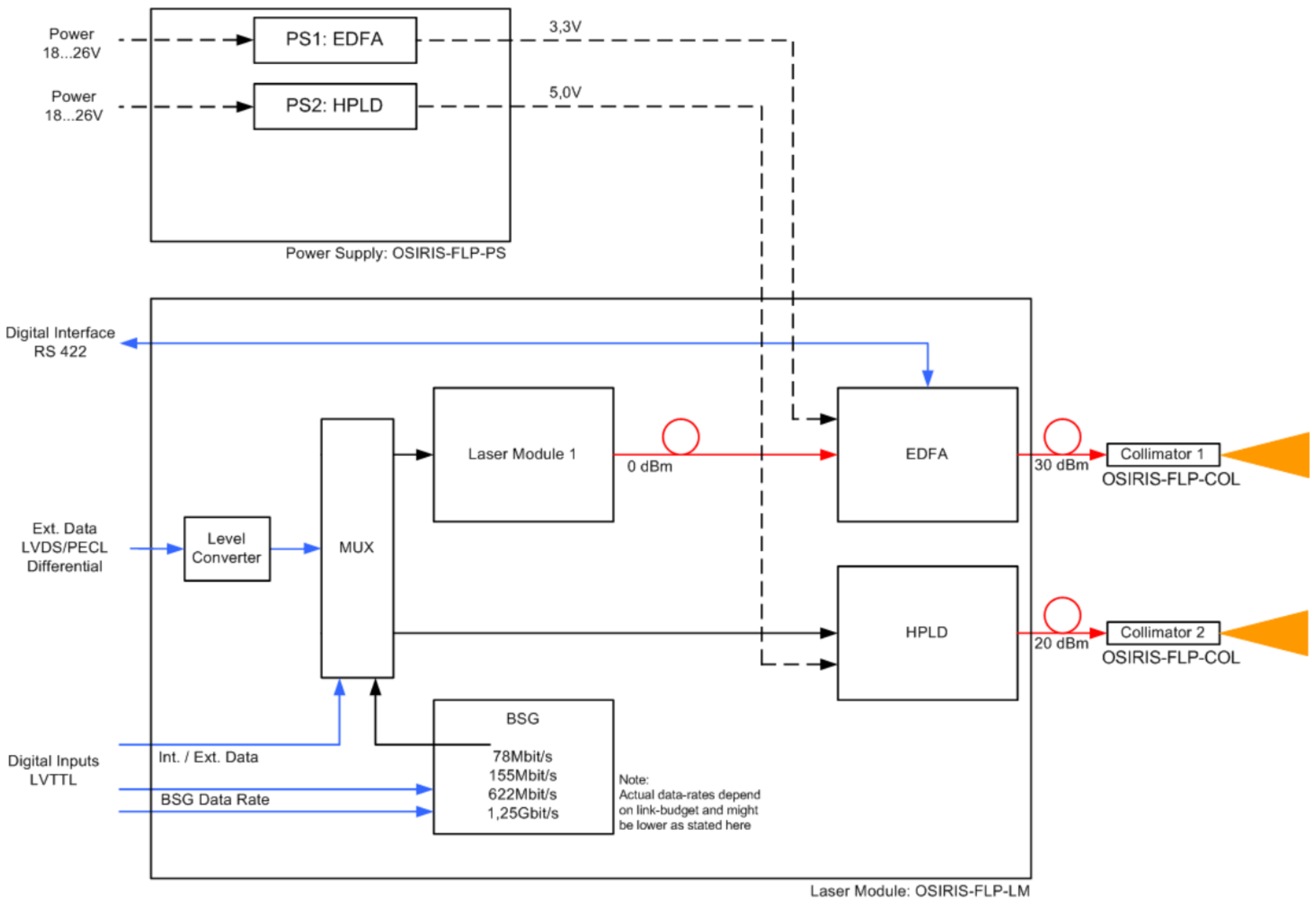


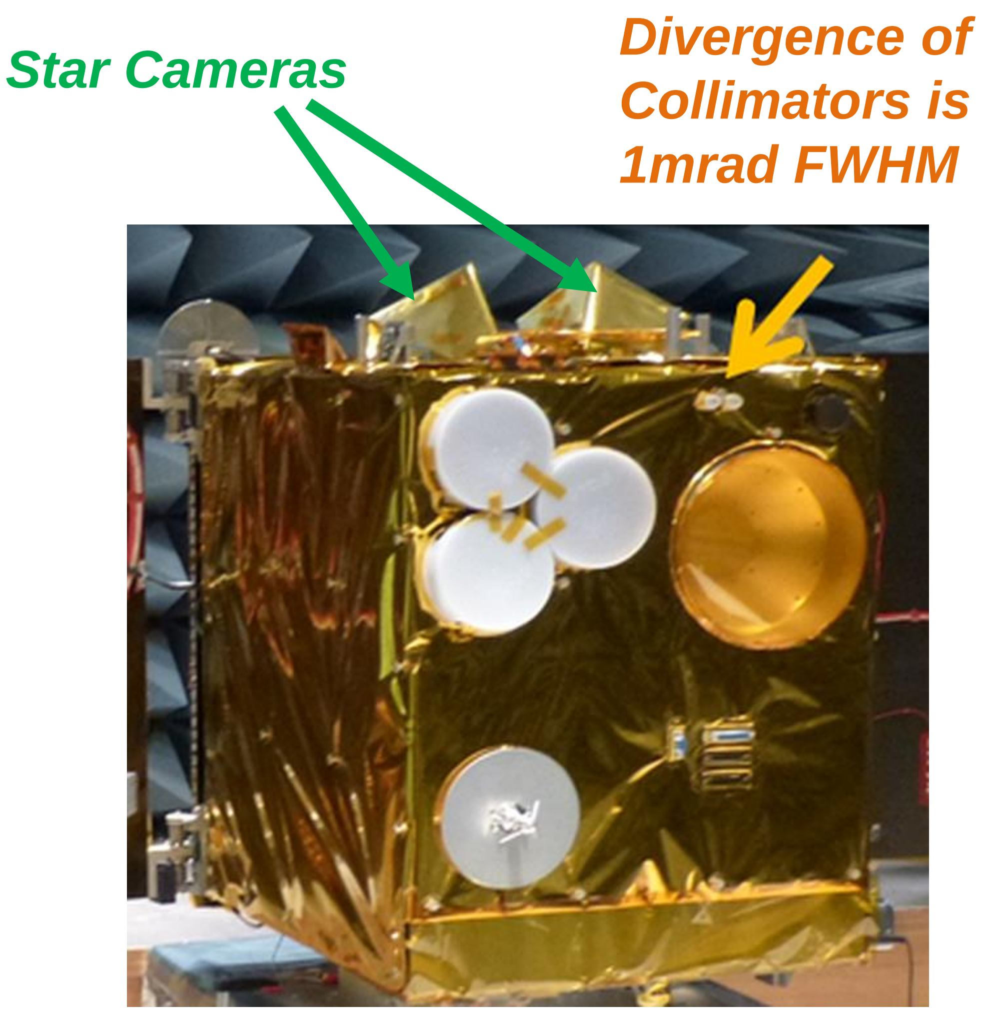
c)
No tracking, full Body-Pointing through Satellite's attitude knowledge from star-camera sensors
→ *OSIRISv1 on Flying Laptop*

Find the angular offset between Star-Cameras and Laser-Direction, after shocks from rocket launch.

OSIRIS*: Optical Space InfraRed downlInk System*

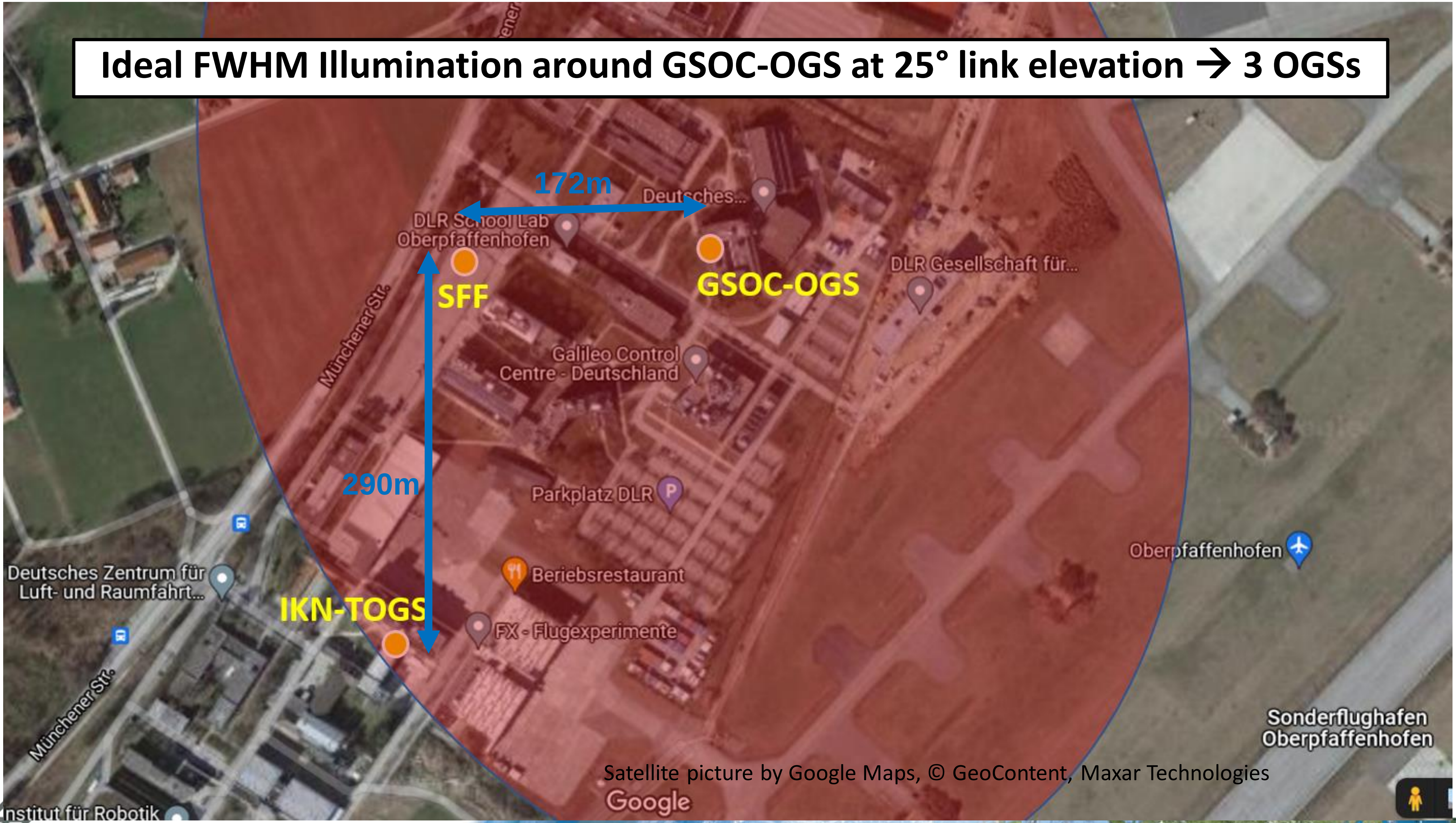
The OSIRISv1 on Flying Laptop





Flying Laptop Satellite,
OSIRIS-transmitters: Collimators below arrow

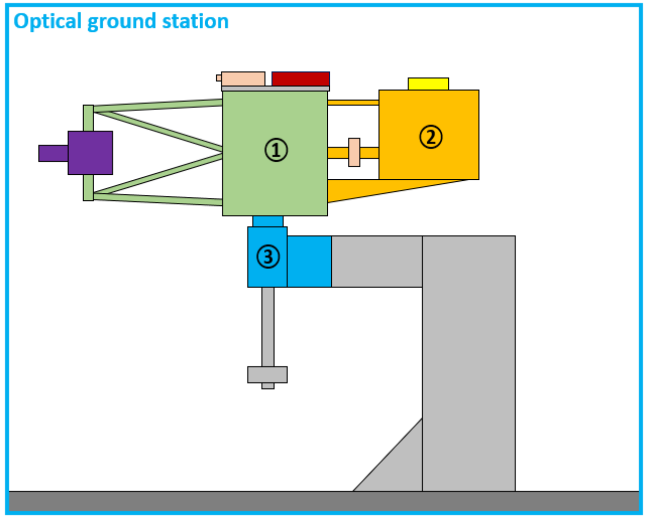
Ideal FWHM Illumination around GSOC-OGS at 25° link elevation → 3 OGSs



Satellite picture by Google Maps, © GeoContent, Maxar Technologies

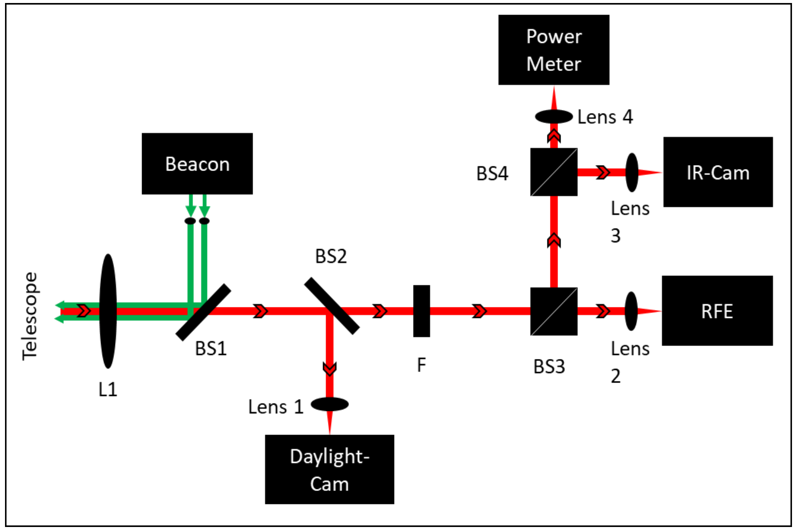
[1] GSOC-OGS

30cm telescope aperture



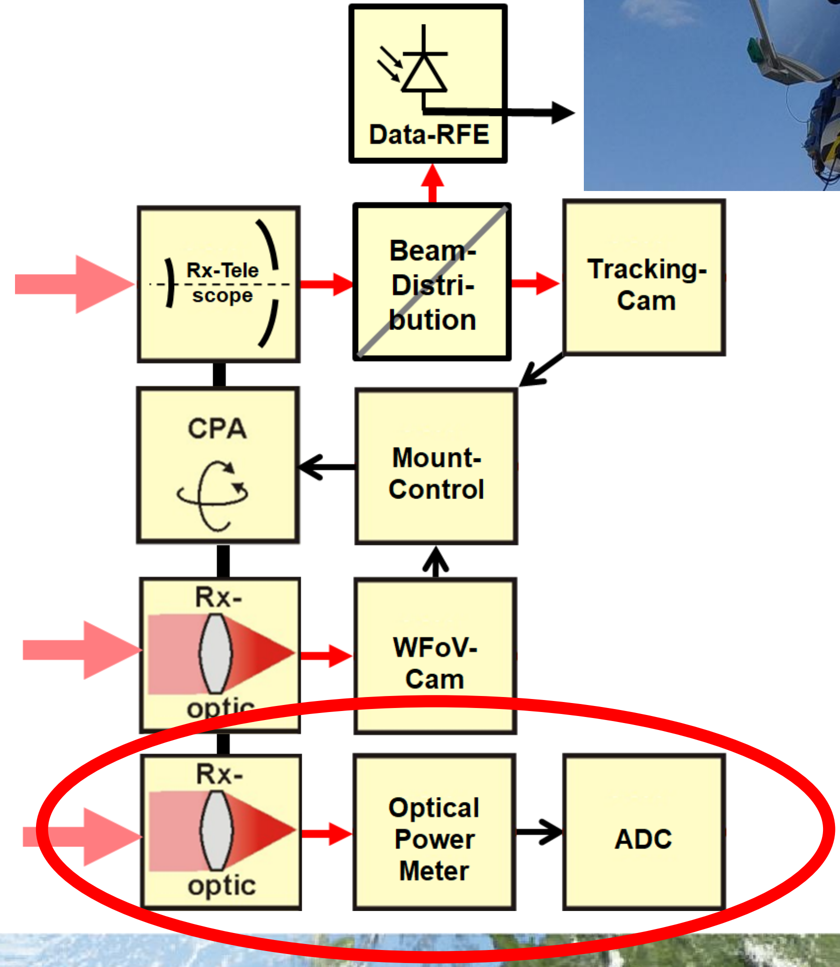
① Telescope ② Benchtop SOFA ③ Alt-Alt-Mount

SOFA:
Small OGS
Focal Assembly



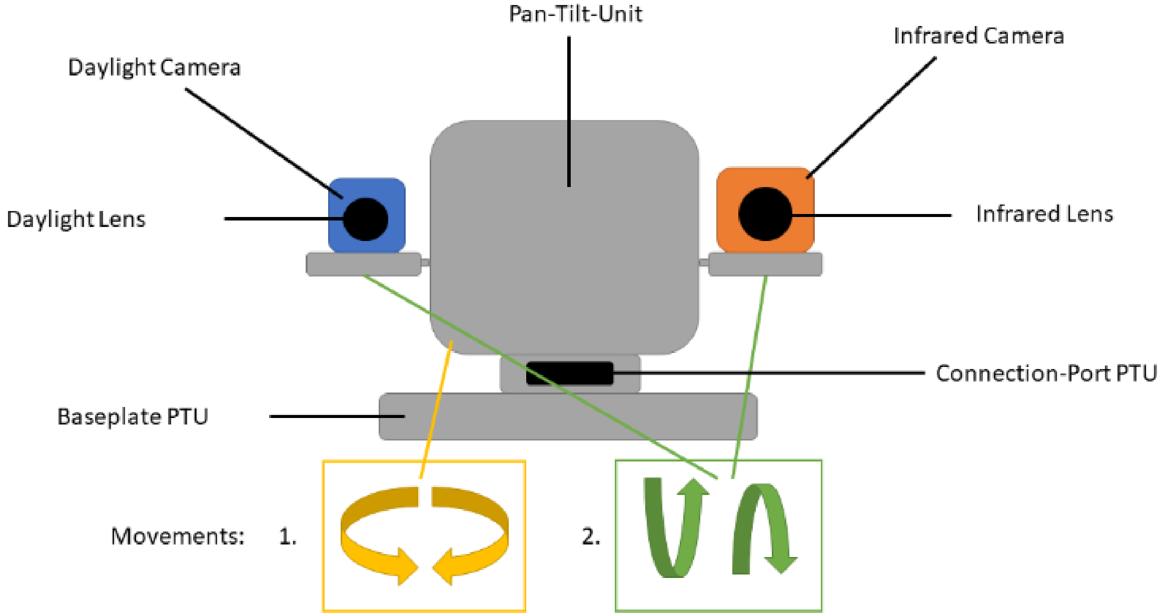
[2] IKN-TOGS

60cm telescope aperture



[3] Satellite Flash Finder (SFF)

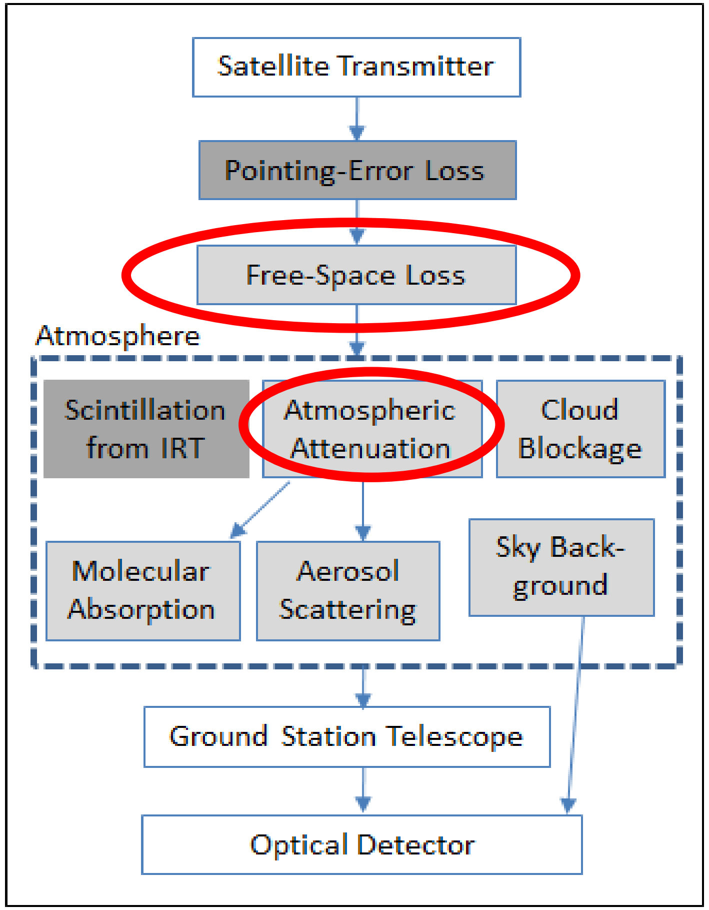
2cm Rx-lens aperture

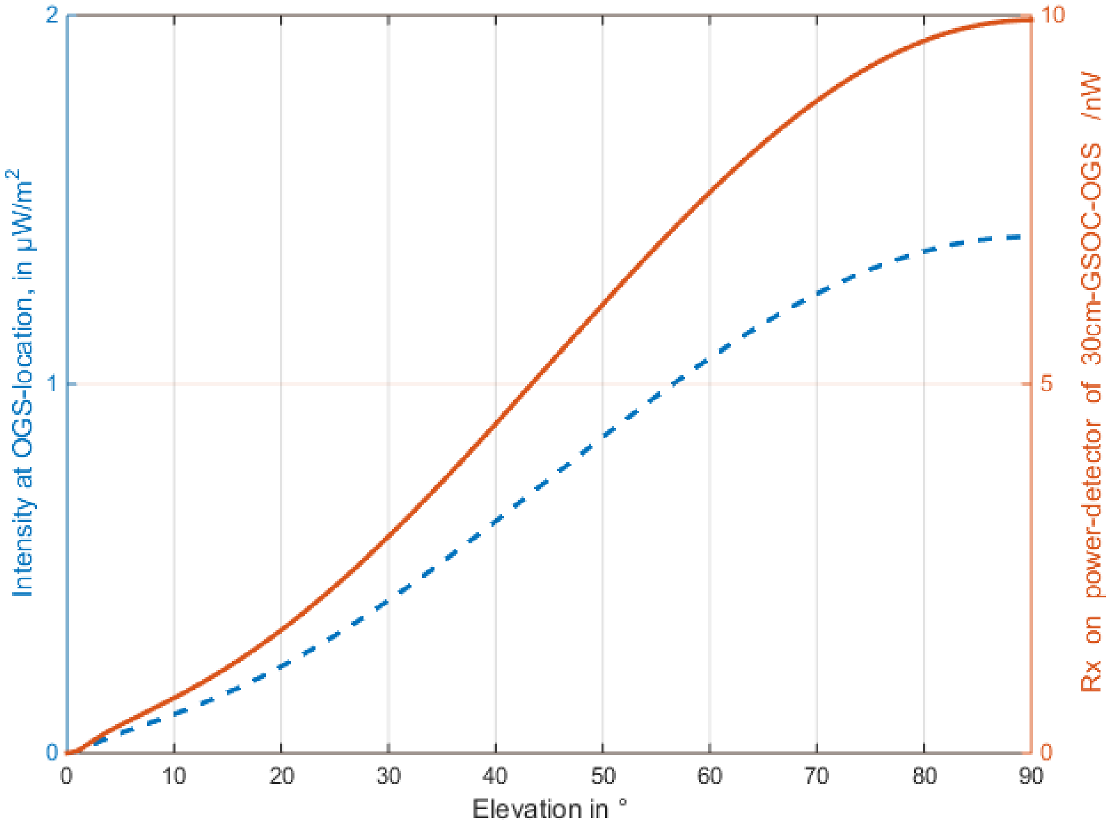


- Primary development-goal was an automated (unattended) hardware to find a first “Flash” from a (scanning) new *OSIRIS* terminal, and identify by time the intended pointing direction of the satellite

- SFF now also serves as a simple and automated intensity sensor, by using the infrared camera and calculating power

Expected Received-Intensity Estimation from LinkBudget

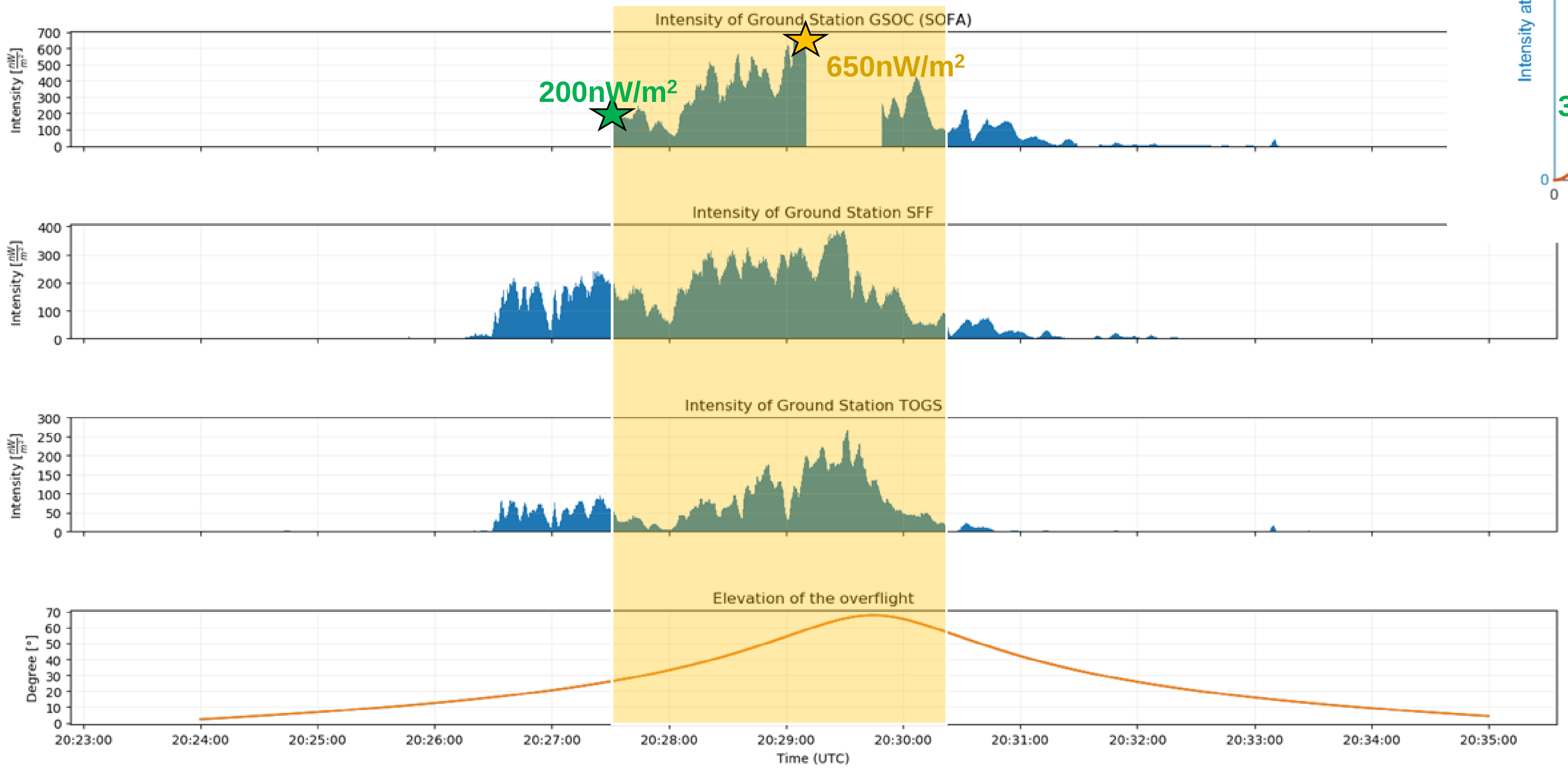


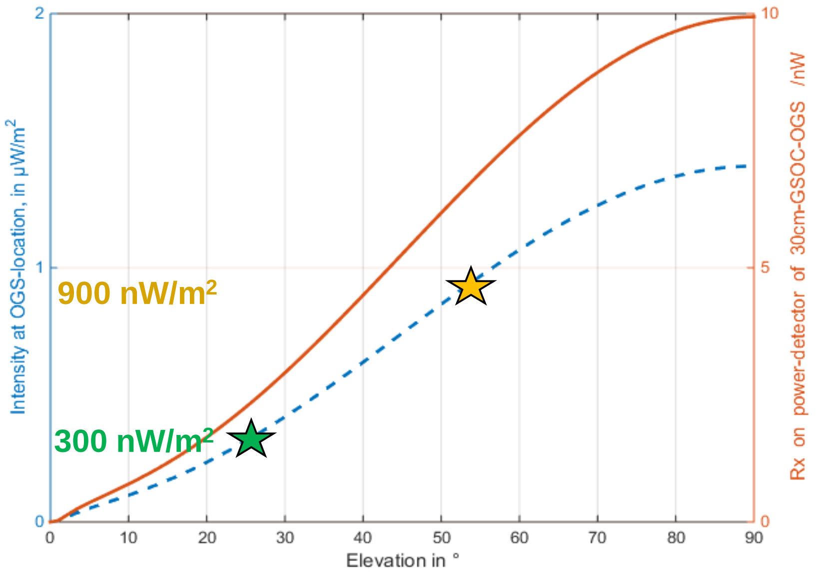


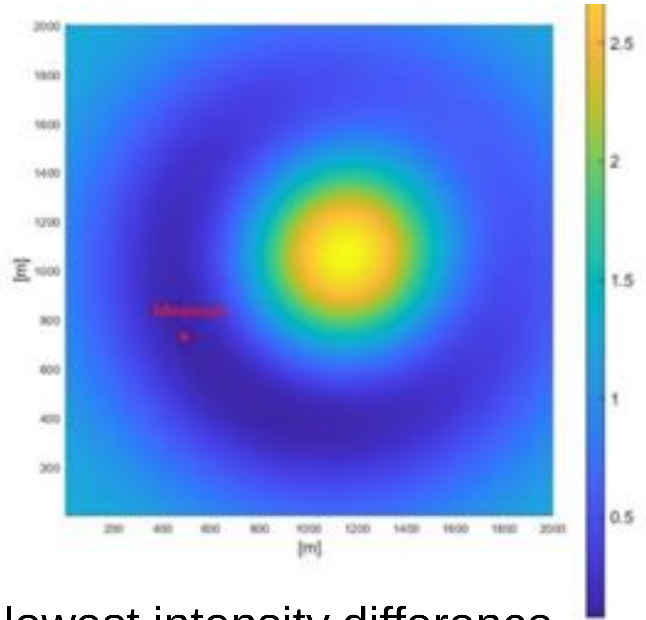
A precise estimation of the axial intensity is required for the algorithm to work accurately

Three Measured *Intensity* Vectors over Time,

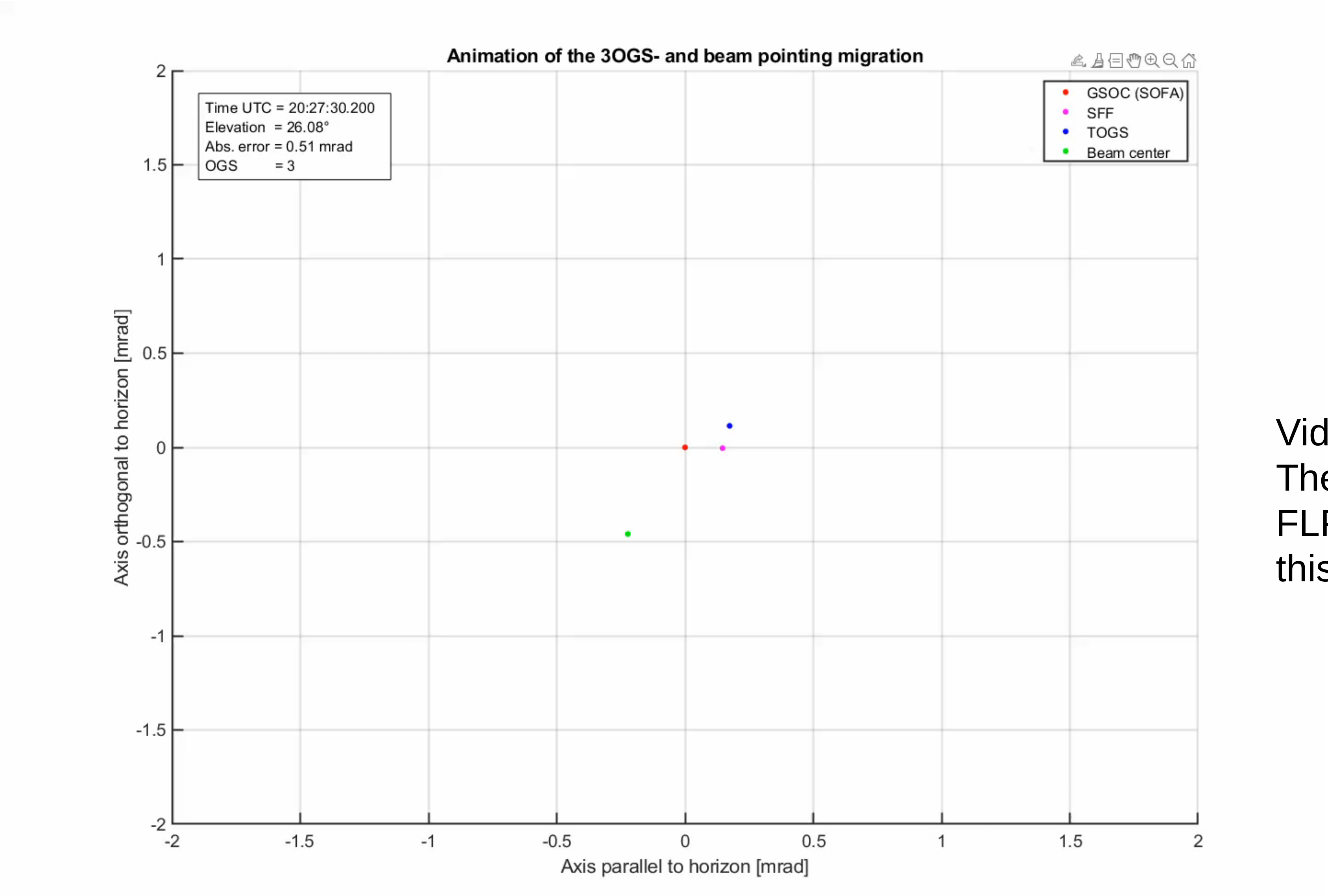
Downlink on 20th October 2021, centered on GSOC-OGS





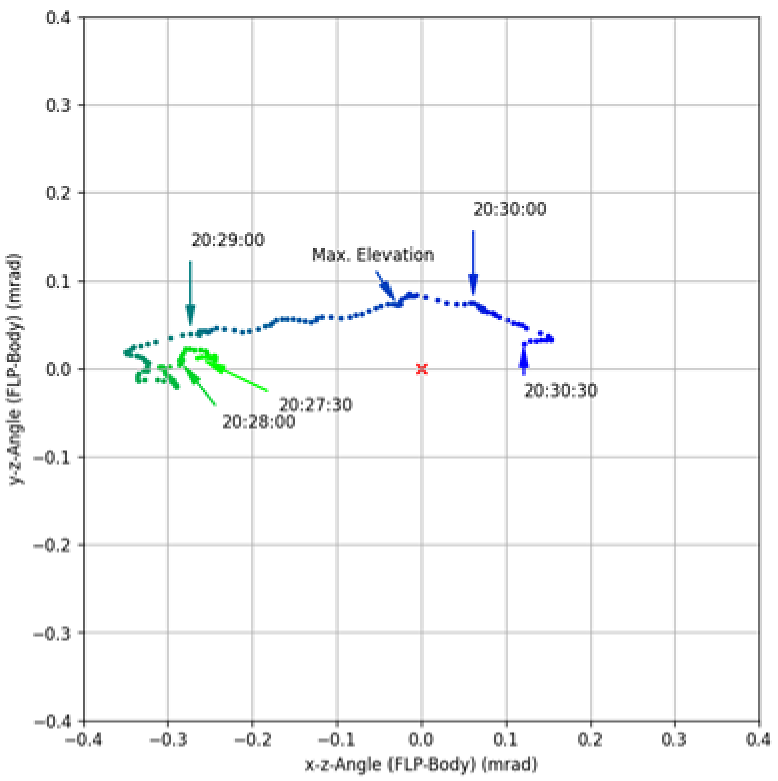


Find offset of lowest intensity difference, between measured and numerical estimation



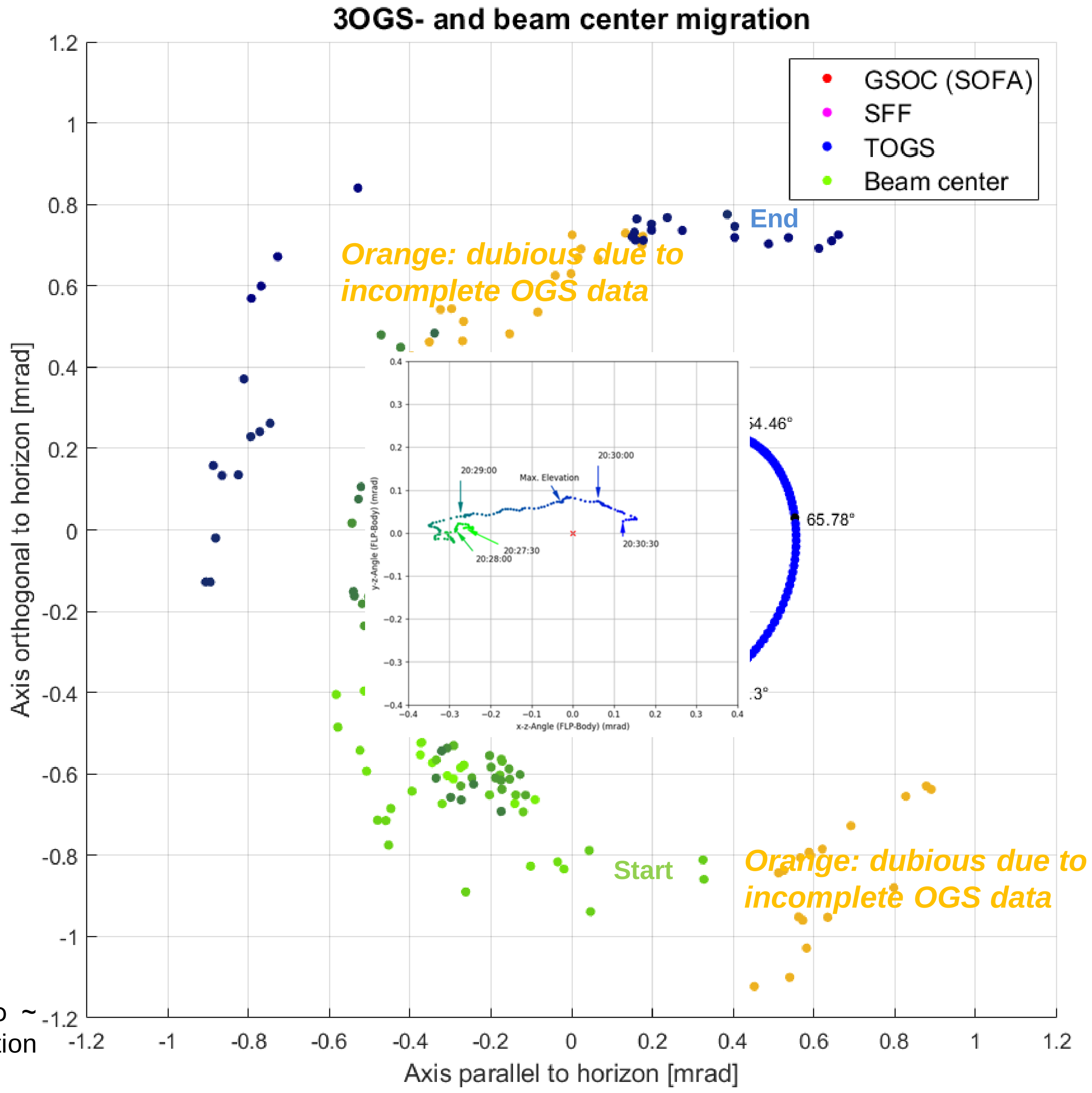
Video:
The 3 OGSs as seen from FLP-satellite, during part of this downlink

Residual spot axis migration derived from 3OGS measurements and estimated by Flying Laptop



FLP estimates its residual pointing error through its Star-Cam data, to ~ 300 x 100 µrad

… but 3OGS verification on ground estimates up to ~ 600 x 800 µrad, and a rather constant offset direction



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Conclusion and Outlook

- This specific downlink showed a rather fixed offset from the satellite, pointing ***~0.6mrad North*** to GSOC-OGS, plus additional dynamic variation
- This remaining Pointing Offset we think stems from downlink-individual thermal offset of the laser collimator versus the star cameras attitude
- Knowledge of maximum intensity is most crucial for the algorithm, this can be ambiguous through uncertain atmospheric attenuation

- An automated SatFlashFinder shall be used for identifying first Laser Signal from any new OSIRIS
- Then use ***Three common SFF Sensors*** for Pointing Calibration, instead of different OGS-types
- … larger spacing of these 3 sensors is required for better decorrelation of intensities and observing larger offset angles